Storage Program Overview

Advanced Research Projects Agency (ARPA-E)

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ARPA-E Program Director: Grids Storage and Distributed Generation

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ARPA-E's Storage Portfolio Has Grown Rapidly

>$200M of Funding for Storage Technology Since 2009

PROGRAM	TECHNOLOGY AREA	FUNDING ($M)	# PROJECTS
OPEN 2009	Transportation & Stationary: Metal Air; Flow cells, capacitors, solid state	36	7
BEEST	Transportation: High Energy Density	32	10
GRIDS	Stationary: Flow cells, conventional cells, SMES, reversible fuel cell, flywheels	38	13
OPEN 2012	Transportation & Stationary: New flow Cell Chemistries; solid state	40	19
AMPED	Transportation & Stationary: Improved BMS algorithms and sensors	30	14
SBIR 2012	Transportation & Stationary: Flow cells, advanced membranes, high-temp cells	13	7
RANGE	Transportation: Robust Lower Energy Density Incorporated into Vehicle Design	36	22

GRIDS & Open FOA FY12 grid storage (Better and Beyond GRIDs) & CHARGES

Valued energy storage technologies that span across a timescale of seconds to hours that deliver grid scale power and outperforms current generation technology in cost and cycle life while decreasing emissions.

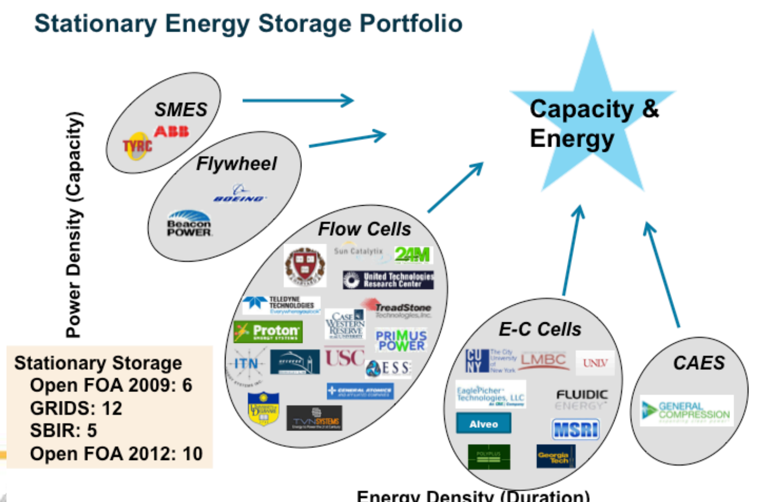
Problem Statement

- GRIDS: High penetration of renewables on the grid creates large changes in power that can span from minutes to hours and lead to grid destabilization.
- OPEN FY12: High cost of new T&D coupled with congested environments decreases asset flexibility and grid reliability.
- CHARGES: Limited path to integrate and valuate new storage technologies in the grid.

Approach

- GRIDS: Focused on a variety of energy storage technologies that deliver power in <u>specific time</u> domains. Cost performance metrics set to be competitive with NGCC spinning reserves and pumped hydro.
- OPEN FY12. Focused on electrochemical energy storage technologies that deliver power across multiple time domains that allows the stacking of grid storage application.
- CHARGES: Develop economic based grid storage duty cycles and performance testing on miro-grid.

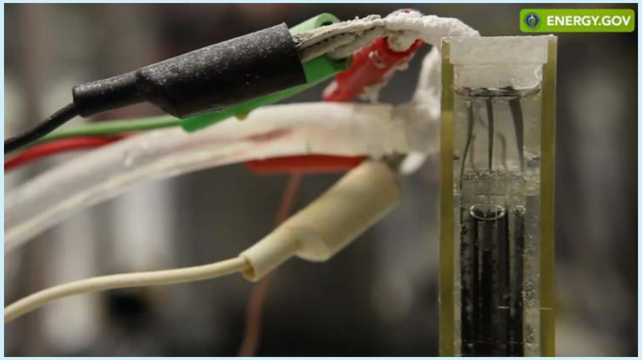
Program Portfolio (solutions)



Scientific & Technical Challenges

- Decrease battery cost, while demonstrating high performance and cycle life.
- Minimizing overpotentials. (kinetics or mass transfer)
- Equilibrium effects as a function of SOC.
- Scalable manufacturing and materials.
- Optimize and decrease system (BOP, power electronics)

Sample ARPA-E Project: CUNY
From High-Risk R&D to Storage Start-up in 48 Months



CUNY Energy Institute R&D Zn-Anode Cell

2010

- $3M ARPA-E award with aggressive life target (2000 cycles) for non-rechargable Zn-MnO_2 alkaline cell
- Technical focus was developing new cathode materials (MnO_2), electrode design, and cycling protocol
- Distinguished academic team with industry partners and T2M experience

CUNY The City University of New York

Urban Electric Power (UEP) Prototype

2014

- >2000 cycles on Zn-MnO_2, now optimizing electrode composition and electrolyte to attain >3000
- UEP founded in 2012; secured additional R&D funding from NYSERDA, BPA, and ConEd
- Closed seed round in 2012; nearing close of Series A funding

URBAN ELECTRIC POWER

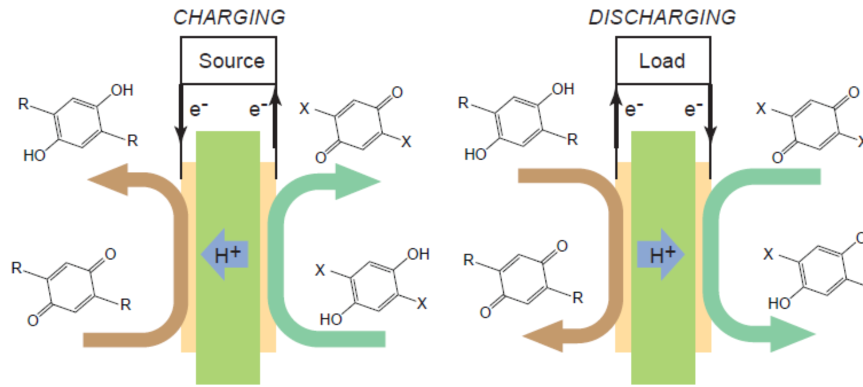
Sample ARPA-E Project: Harvard University
Novel, Low-Cost Flow Battery is Maturing Rapidly

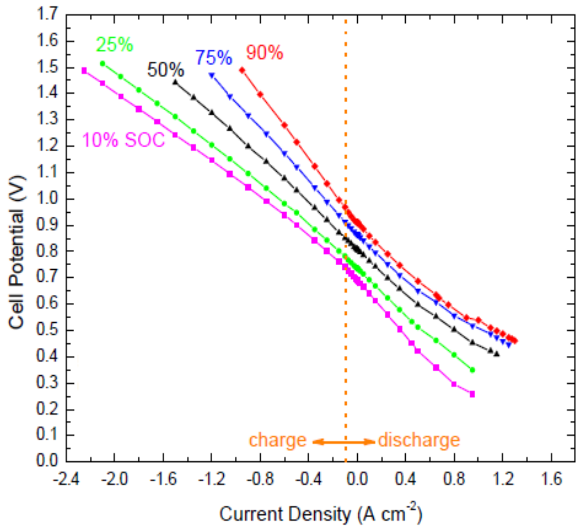
Quinone-Bromide Chemistry

- **Low Cost Electrolyte:** <$27/kWh at scale
- **Fast Kinetics:** 1000x faster than VO_2^+/VO^{2+}
- **Modest Stack Costs:** carbon paper electrodes, no catalyst
- **High Power:** > 600 mW/cm^2 (peak)
- **Durable:** > 99.8% capacity retention (700 cycles)
- **Non-Hazardous:** Aqueous, non-toxic electrolyte

Quinone-Quinone Chemistry

- Currently under development





Nature **505**, 195-198 (2014) doi:10.1038/nature 12909

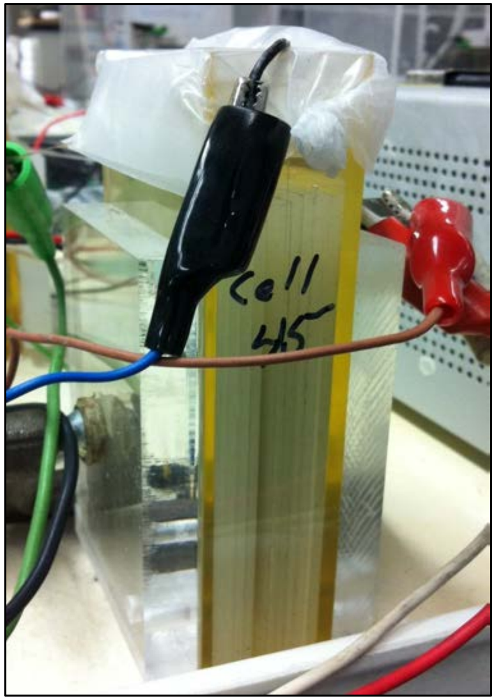
Harvard Department of Chemistry & Chemical Biology

HARVARD School of Engineering and Applied Sciences

Sustainable Innovations

arpa·e CHANGING WHAT'S POSSIBLE

How do we create a path to scale innovation?



- Need to demonstrate performance, cycle life, cost and manufacturability of new technology at a reasonable scale
- How can we screen and optimize promising technologies before we fund costly scale up?

CHARGES: Cycling Hardware to Analyze and Ready Gridscale Electricity Storage (CHARGES)

1. Economic Valuation
2. Test Protocols
3. Battery Testing
4. Microgrid Testing
5. Commercial Deployment Pathway

- Existing ARPA-E performers provide single cell and multi-cell systems for testing
- CHARGES awardees will provide analysis and testing expertise and the facility where new storage technologies can be tested under controlled conditions as well as under “real world” microgrid operating conditions
- CHARGES awardees also will facilitate information exchange with potential buyers of stationary storage systems, including utilities and IPPs
- The objective is to resolve fundamental challenges in physics and chemistry for emerging stationary storage technologies before substantial scaling is required
- Will also generate credible performance data in the process

www.arpa-e.energy.gov